

## N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM  
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT  
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED  
IN THE INTEREST OF MAKING AVAILABLE AS MUCH  
INFORMATION AS POSSIBLE

# 1. ADVANCED MICROBIAL CHECK VALVE DEVELOPMENT

FINAL REPORT

BY

G. V. COLOMBO

(D. R. GREENLEY

5. JUNE 1980

(NASA-CR-163577) ADVANCED MICROBIAL CHECK  
VALVE DEVELOPMENT Final Report (Umpqua  
Research Co., Myrtle Creek, Ore.) 34 p  
HC A03/MF A01 CSCL 06K

N80-33094

Unclas  
G3/54 28795

Distribution of this Report is provided in the interest of information exchange. Responsibility for the contents resides in the author or organization that prepared it.

4.  
PREPARED UNDER CONTRACT No. NAS9-15854

BY

3. UMPQUA RESEARCH COMPANY  
MYRTLE CREEK, OR

FOR

LYNDON B. JOHNSON SPACE CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



---

UMPQUA  
RESEARCH

ADVANCED MICROBIAL CHECK VALVE DEVELOPMENT  
FINAL REPORT

JUNE 1980

NAS9-15854

---

BY

G. V. COLOMBO  
D. R. GREENLEY

Prepared for Lyndon B. Johnson Space Center, National Aeronautics and  
Space Administration, Under Contract NAS9-15854

UMPQUA RESEARCH COMPANY  
P.O. Box 791, MYRTLE CREEK, OREGON 97457

## TABLE OF CONTENTS

	Page
INTRODUCTION-----	1
OBJECTIVES-----	2
TASK 1, ADVANCED MCV APPLICATIONS-----	3
TASK 2, RETROFIT FLIGHT PROTOTYPE MCV UNITS-----	17
TASK 3, MANUFACTURE FLIGHT CERTIFIED RESIN-----	17
TASK 4, RESIN REGENERATION-----	18
TASK 5, ADVANCED MCV PROTOTYPE-----	23

## FIGURES

FIGURE 1, TEST EQUIPMENT-----	6
FIGURE 2, RESIN REGENERATION-----	21
FIGURE 3, REPEATED RESIN REGENERATION-----	22
FIGURE 4, ADVANCED MCV-----	24
FIGURE 5, ADVANCED MCV PROTOTYPE-----	25
FIGURE 6, MCV CARTRIDGE PROTOTYPE-----	26

## TABLES

TABLE 1, ESTIMATED COMPOSITIONS OF WATER STREAMS-----	3
TABLE 2, SUMMARY OF MCV CHALLENGES-----	13
TABLE 3, TENTATIVE WASH WATER STANDARDS-----	16

APPENDIX -----	28
----------------	----

## INTRODUCTION

Under previous contract effort (NAS9-15616) a flight certified assembly identified as a Microbial Check Valve (MCV) was developed and tested. The MCV is a canister packed with an iodinated anionic exchange resin. The device is used to destroy organisms in a water stream as the water passes through the device. The device is equally effective for fluid flow in either direction and its primary method of organism removal is killing rather than filtering.

The Microbial Check Valve (MCV) has been successfully developed for the Space Shuttle to: 1) disinfect fuel cell water; and 2) prevent back contamination of the stored potable water supply. One version of the device consists of a "high residual" iodinated resin bed that imparts approximately 2 ppm of iodine to the fuel cell water as it flows to the potable water tanks. A second version of the device consists of a "low residual" iodinated resin bed. One of these "low residual" beds is located at each use port in the potable water system for the dual purpose of removing some iodine from the potable water as it is dispensed and also to prevent back contamination of the potable supply. A third version of the device, which contains the "high residual" resin, is used to disinfect water used in the EMU.

The Microbial Check Valve has potential space applications beyond the basic Space Shuttle mission. It appears to be also suited for use in advanced water reclamation systems that NASA has under development for the disinfection of humidity condensate, wash water and human urine.

So far, the only effective method for maintaining microbial control in development space-type water reclamation systems has been heat at pasteurization temperatures and an iodine system which requires an iodine monitor and injection system. It is recognized that these are relatively high penalty approaches, but no other completely satisfactory method has been developed.

Methods including the use of: microbial filters, U-V radiation, chlorination and silver ions have been evaluated and all have been found deficient. It is felt that the microbial check valve may be able to satisfactorily replace heat as a microbial control method in some or all of these reclamation systems and thereby effect a large savings in weight, power and cost.

#### OBJECTIVES

The objectives of this effort were:

- a. To evaluate the high residual (2 ppm) iodinated resin developed for disinfecting Space Shuttle fuel cell water and define its limitations, if any, for use with space-type water reclamation systems.
- b. To retrofit three flight prototype MCVs previously delivered to NASA to reflect the design of the flight units delivered under NAS9-15616.
- c. To provide quantities of flight certified low residual and high residual resins to support the Space Shuttle Operation Flight Test program plus the first six operational flights.
- d. To evaluate the reuse potential of resin and if economically practical to develop procedures to accomplish this.
- e. To develop and demonstrate a more efficient container concept for the flight MCVs.

Task 1. ADVANCED MCV APPLICATIONS

Six potential advanced MCV applications are projected for water streams in space-type water reclamation systems. These six water streams are listed in Table 1 in what is felt to be an increasing order of difficulty for the MCV. The principal dissolved materials that must be dealt with, and their estimated concentrations, are listed after each of the water streams.

<u>Water Stream</u>	<u>Major Contaminant</u>	<u>Amount ppm</u>
humidity condensate	ammonia	18
	ethanol	8
	acetaldehyde	1
Urine distillate without carryover	ammonia	20
	ethanol	10
	acetaldehyde	2
Wash water after reverse osmosis treatment	cleansing agent	40
	sodium chloride	20
	lactic acid	10
	urea	7
Wash water after chemical addition/filtration	treatment chemical	20
	cleansing agent	50
	sodium chloride	40
	lactic acid	35
	urea	13
Urine distillate with carryover	urea	75
	sodium chloride	45
	potassium sulfate	15
	potassium chloride	9
	creatinine	8
	ammonium hippurate	8
	magnesium sulfate	4
	phenol	2
	potassium phosphate	1

<u>Water Stream,cont.</u>	<u>Major Contaminant</u>	<u>Amount ppm</u>
Raw wash water with filtration	cleansing agent	110
	sodium chloride	40
	urea	35
	lactic acid	13

The approach to this task was to first challenge resin beds with solutions that contain known concentrations of the following contaminants: ammonia, ethanol, acetaldehyde, sodium chloride, urea, lactic acid, two cleansing agents, and two treatment chemicals.

Initial tests examined the effects of each contaminant separately to establish contaminant concentration and resin life/effectiveness relationships. Later tests combined contaminants to simulate typical reclamation system use points. Finally, tests were conducted using real urine to simulate typical "carry over" conditions and real wash water to simulate the wash water application.

#### 1.1 MCV CHALLENGES

Challenges of the resin were performed by pumping prepared solutions through a bed of resin and monitoring the influent and effluent for significant changes in the pH, specific conductivity and iodine residual. The tests were conducted with 8 mm dia x 76 mm test beds of 2 ppm resin and 10 ml/min flow rate at room temperature. The concentrations of the solutions were varied in an effort to identify contaminant levels that would not adversely affect the resin. The contaminant was assumed to have no effect on the resin if the effluent  $I_2$  residual was within 10% of the control bed. The overall test direction was to start with single-contaminant challenges and work up to the multiple-contaminant test water streams. With each test contaminant or test stream, the concentration was either increased to the failure point of the resin, or decreased until there was no adverse affect on the resin. In some cases the test streams reached.



very high levels without significant effects on the test stream interfered with the Leuco-crystal violet test reagents, precluding any measurement of the  $I_2$  residuals.

CHALLENGE WITH  $(NH_4)_2SO_4$  - Dilutions of  $(NH_4)_2SO_4$  were prepared by adding 50, 5, 0.5 and 0 grams of  $(NH_4)_2SO_4$  to four 5 l aliquots of deionized, (D.I.) water. This resulted in challenge solutions of 1% (10,000 ppm) 0.1% (1000 ppm) 0.01% (100 ppm) and a control deionized water. These solutions were added to feed tanks and individually pumped through 4 respective resin beds (Figure 1). The flow rates were adjusted to  $10 \pm 0.5$  ml/min and maintained at that rate for the duration of the challenge. The effluents from the control bed and from the bed being fed to 0.01% solution had iodine residuals of a little less than 2 ppm. The effluents from the 0.1% and the 1% beds was about 2.2 ppm. The slight increase indicates that the  $(NH_4)_2SO_4$  has the ability to strip iodine from the resin, but since it occurred only at high levels of  $(NH_4)_2SO_4$ , it was not considered to be a significant effect. One thousand ppm  $(NH_4)_2SO_4$  is a much greater concentration than will be encountered by the resin in actual use.

CHALLENGE WITH  $NH_4OH$  - Challenges of the resin were conducted at 0.1, 1, 10, 100, 1000 and 10,000 ppm as  $NH_3$ . Iodine was stripped from the resin at greatly accelerated rates, approximately 100 times normal at 1% (10,000 ppm)  $NH_3$  down to 2 times normal at 1 ppm  $NH_3$ . At 0.1 ppm there was no noticeable effect of the ammonia on the resin. The effect of  $NH_4OH$  on the resin is very marked. At the higher concentrations, the resin was visibly decolorized towards the end of a 6 hour challenge. The stripping rate is readily evident at the 1% level. The 1 hour  $I_2$  residual reading was about 150 ppm  $I_2$  residual steadily decreased down to 25 ppm at the end of the run.

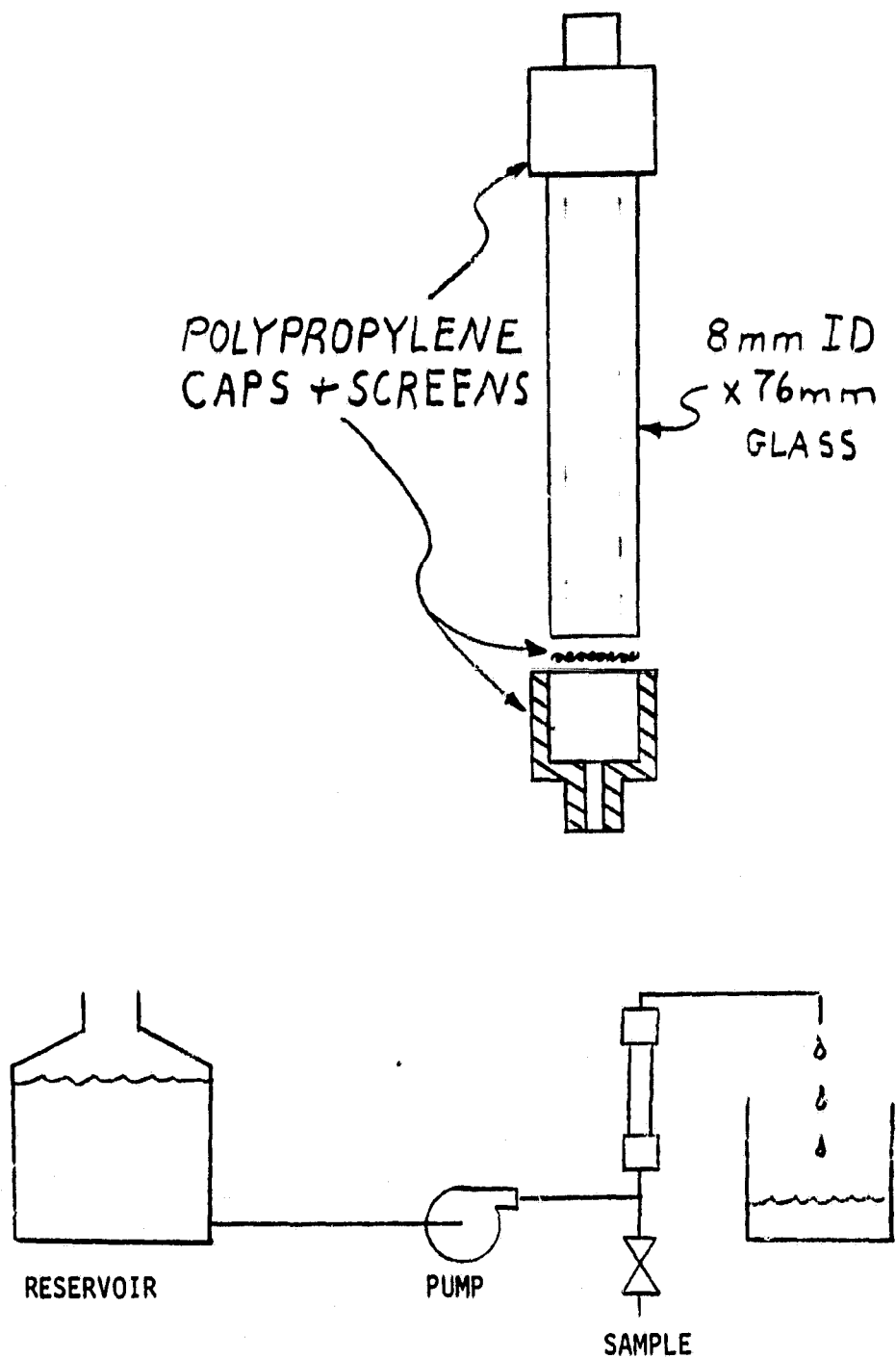


FIGURE 1, TEST EQUIPMENT

UREA - Urea challenge solutions were prepared at 0.01% (100 ppm) 0.1% (1000 ppm) and 1% (10,000 ppm). There was no significant effect of the urea on the resin with any of the levels tested, up to 10,000 ppm. It appears that urea to 10,000 ppm has no adverse effects on the resin

CALSOFT L-40\* (Sodium Sulfonate) - Challenge solutions were prepared at 0.01% (100 ppm), 0.025% (250 ppm), and 0.05% (500 ppm) active ingredients. Calsoft at 0.05% had an  $I_2$  demand that exceeds the capacity of the bed, i.e., there was no  $I_2$  residual in the effluent stream. Solutions of 0.025% and 0.01% had no noticeable effect on the  $I_2$  residual of the resin. The  $I_2$  demand of the sodium sulfonate was calculated to be about  $10^{-2}$  mg  $I_2$ /mg sodium sulfonate. Sodium sulfonate would appear to be allowable in the water streams at levels not to exceed 250 ppm, active ingredients.

ML11\*\*- ML11 soap was diluted to 0.001% (10 ppm), 0.01% (100 ppm) and 0.1% (1000 ppm), calculated as active ingredients. The soap solutions formed a flocculent precipitate upon addition of the iodine test reagents, so spectrophotometric measurement was precluded. Standards were prepared by adding known quantities of iodine to the soap solutions and then used as a basis for visual comparison to estimate the  $I_2$  present in the effluents. The ML11 doesn't have a significant immediate  $I_2$  demand, but after a 10 minute exposure, the  $I_2$  level was significantly reduced in the 100 and 1000 ppm soap solutions.

HUMIDITY CONDENSATE - A simulated humidity condensate water was prepared with 18 ppm ammonia, 16 ppm ethanol and 1 ppm acetaldehyde. The simulated humidity condensate was supposed to have only 8 ppm ethanol but a post-experiment review of calculations and procedures revealed a miscalculation that resulted in twice as much ethanol being used as was called for. Since this error made the experiment even more conservative, no retest was performed. There were no adverse effects of this solution on the  $I_2$  residual of the resin.

\*40% Sodiumdodecylbenzenesulfonate - Pilot Chemical Co., Los Angeles, CA

\*\*ML11 Soap, Rochester Germicide Inc., Rochester, N.Y.

NaOH - Challenges were made from 0.04 to 1 ppm as  $\text{OH}^-$ . At 1 ppm, the NaOH stripped all of the  $\text{I}_2$  from the resin within 4 hours. At 30 minutes into the challenge, the iodine residual in the effluent was about 160 ppm. At 90 minutes the resin had been rinsed down to 32 ppm and by 4 hours, essentially all the iodine had been stripped from the resin. At 0.04 ppm  $\text{OH}^-$  the resin was being stripped of  $\text{I}_2$  at about 15 times the normal rate. It is evident that even at very low levels ( $\text{pH} > 7$ )  $\text{OH}^-$  is quite deleterious to the resin.

NaCl - Challenge solutions were prepared at 50,000, 25,000, 10,000, 10, 1 and 0.1 ppm NaCl. Slightly elevated  $\text{I}_2$  residuals were noted at concentrations from 50,000 to 10 ppm, but not high enough to significantly deplete the resin. One and 0.1 ppm concentrations of NaCl had virtually no effect. There should be no problem with the resin up to 5% NaCl or higher.

LACTIC ACID - Lactic acid challenge dilutions were prepared at 1% (10,000 ppm) 0.1% (1000 ppm) and 0.01% (100 ppm). The 1% lactic acid solution had a slight inhibitory effect with  $\text{I}_2$  residual. The  $\text{I}_2$  residual ranged between 1.8 and 2.0. This challenge was not taken to the point of resin failure because 1% lactic acid is a much higher concentration than the resin will be subjected to in actual use. There appeared to be no significant adverse effects of lactic acid on the resin.

ACETALDEHYDE - Acetaldehyde challenge solutions were prepared at 0.01% (100 ppm) 0.1% (1000 ppm) and 1% (10,000 ppm). There was no significant change in the  $\text{I}_2$  residual even at 1% concentration.

URINE DISTILLATE WITHOUT CARRYOVER - This water stream was simulated by preparing a D.I.  $\text{H}_2\text{O}$  solution with 20 ppm ammonia, 20 ppm ethanol and 2 ppm acetaldehyde. A more conservative test stream was prepared containing twice the concentration of all ingredients. The simulated water stream was supposed to have only 20 ppm ethanol but a post-experiment review of calculations and

procedures revealed a miscalculation that resulted in twice as much ethanol being used as was required. The miscalculation also carried over into the second, more conservative water stream, so it has 4 times the ethanol originally needed. There were no adverse effects on the  $I_2$  residual of the resin.

WASH WATER AFTER REVERSE OSMOSIS TREATMENT - This water stream was simulated by adding 40 ppm active ingredients of ML11 soap, 20 ppm NaCl, 10 ppm lactic acid and 7 ppm urea. This water stream had no adverse effect on the  $I_2$  residual in the effluent water.

SIMULATED URINE DISTILLATE WITH CARRYOVER - A simulated water stream was prepared in D.I.  $H_2O$  by the addition of: 75 ppm urea, 45 ppm NaCl, 15 ppm potassium sulfate, 9 ppm potassium chloride, 8 ppm creatinine, 8 ppm ammonium hippurate, 4 ppm magnesium sulfate, 2 ppm phenol, 1 ppm potassium phosphate. This water stream had an immediate  $I_2$  demand that exceeded the capacity of the resin bed to produce an  $I_2$  residual.

RAW WASH WATER WITH FILTRATION - A simulated water stream was prepared in D.I.  $H_2O$  by the addition of: 110 ppm ML11 cleansing agent, 40 ppm sodium chloride, 35 ppm urea and 13 ppm lactic acid. This water stream turned turbid with the addition of the iodine test reagents, precluding spectrophotometric measurement. Approximate  $I_2$  levels were estimated by visual comparison with iodine standards prepared in the test stream water. This test stream has an immediate  $I_2$  demand of about 1 ppm  $I_2$ .

URINE DISTILLATE WITH CARRYOVER - BREAKDOWN - In an attempt to identify which components created the  $I_2$  demand, they were run separately in the concentration used for the simulated test stream formulation. The creatinine and hippuratic acid had no significant effect on the  $I_2$  residual,

but the phenol had an  $I_2$  demand that exceeded the capacity of the resin bed.

PHENOL - To determine potentially acceptable phenol levels, solutions were made up at 0.1 ppm, 0.5 ppm and 1 ppm in D.I.  $H_2O$  and pumped through the resin beds. At 0.1 ppm the phenol has about 0.5 ppm immediate  $I_2$  demand. At 0.5 ppm the demand is about 1 ppm and at 1 ppm phenol the demand is about 1.5 ppm  $I_2$ .  $I_2$  residual tests taken on samples after one-half hour exposure showed no more  $I_2$  loss than the control. So it appears that the  $I_2$  demand is immediate.

PRETREATMENT CHEMICALS - Most urine recovery systems use pretreatment chemicals to minimize the decomposition of urea to ammonia which carries over into the reclaimed water. The pretreatments usually contain acid and a strong oxidizing agent to minimize thermal degradation, and a biocide to minimize microbial decomposition. The two pretreatment chemical selected for testing were:

1. McDonnell Douglas (MDAC) suspension containing 4.12 grams potassium dichromate ( $K_2Cr_2O_7$ ), 11.3 grams  $H_2SO_4$ , 1.4 grams  $CuSO_4 \cdot 5H_2O$ , 2.4 grams Dow H-10 antifoam and 13 grams  $H_2O$ .
2. Life Systems, Inc. treatment suspension containing 11.3 grams  $H_2SO_4$ , 11.7 grams Povidone, 2.4 grams Dow H-10 antifoam and 25 grams  $H_2O$ .

Both treatment chemicals, when added to the water in the prescribed concentrations, so grossly discolored the water that  $I_2$  determination was not possible. It was decided to dilute the MDAC treatment chemical down to where the chrome concentration is at the drinking water limit. The logic is that the chrome concentration will exceed the drinking water limits before the treatment chemical itself will prove deleterious to the resin. The MDAC treatment chemical was diluted to give chrome concentrations of 0.05, 0.5 and 5 ppm.

During the actual challenge it was noted that the iodine residual in the effluent seemed to increase with the exposure time. This is explained by the fact that potassium dichromate is a strong oxidant and thus is a positive interference in the iodine test. Since the color changed rather rapidly, it was not possible to make any  $I_2$  determinations. The Life Systems suspension contains free  $I_2$ , thus has no  $I_2$  demand on the resin.

RAW URINE - Assuming the urine to be 5.5 to 7% solids, approximately 50% of which is urea, the urine was diluted out to the following concentrations (given in % urine and approximated ppm urea) in D.I.  $H_2O$ : 1% urine (150 ppm urea); 0.5% urine (75 ppm urea); 0.25% (38 ppm urea); 0.1% urine (15 ppm urea); 0.05% urine (7.5 ppm urea); 0.02% urine (3 ppm urea). All the urine dilutions down to 0.25% (38 ppm urea) had an  $I_2$  demand that exceeded the capacity of the resin. The immediate iodine demand of the 0.1% (15 ppm urea) urine solution was about 1 ppm. The iodine demand of the 0.02% urine (3 ppm urea) was about 0.1 or 0.2 ppm  $I_2$ .

WASH WATER AFTER FLOCCULATION/FILTRATION - A simulated solution was prepared in D.I.  $H_2O$  by adding 50 ppm ML11 soap (active ingredients) 20 ppm  $FeCl_3$  as the treatment chemical, 40 ppm NaCl, 35 ppm lactic acid and 13 ppm urea. This water stream has an immediate iodine demand, about 0.5 ppm at this composition.

RAW, TREATED URINE - To test the pretreatment chemicals under more realistic conditions 0.1% urine samples were treated with 5 ml/l of the treatment chemicals. These pretreated raw urine test streams were then pumped through the resin beds. The resulting effluents showed no adverse effects, very little difference between the control  $I_2$  residuals and the test stream residuals.

## 1.2 MCV CHALLENGE SUMMARY

The results of the challenges with individual chemicals, simulated waste streams and real waste streams are summarized in Table 2.

The tests with the individual chemicals which are the major constituents of waste streams that will be subjected to water reclamation show no effect at very high levels. Tests with  $\text{NH}_4\text{OH}$  and  $\text{NaOH}$  resulted in  $\text{I}_2$  stripping by  $\text{OH}^-$  ions which is to be expected from the strong base resin. Ammonium ion has very little if any effect when the pH is held below 7. The only chemical which showed a high  $\text{I}_2$  demand was phenol, however at levels well above those expected or allowed in reclaimed water.

Raw urine has a fairly high  $\text{I}_2$  demand which is significantly reduced by the addition of the two pretreatment chemicals currently being used in water reclamation systems. When these systems are operating normally and producing potable water, the MCV will iodinate the effluent with no difficulty. Upsets or malfunctioning systems could produce water with up to 1000 ppm pretreated urine content, and the MCV would still maintain an  $\text{I}_2$  residual.

Tentative wash water standards are shown in Table 3. Depending on the iodine demand of the allowable 200 ppm TOC, and assuming the pH can be kept below 7, the MCV should promise to be an attractive method of microbial control. Results reported in Reference 1\* on the Springborn system show finished water with organic levels well below the tentative standards, thus the MCV should have no problems with this water. Reported soap residuals of approximately 50 ppm ML11 after the flocculation step indicates that the MCV could be used at this point in

\* Contract NAS9-15369, Springborn Laboratories, July 15, 1978.



TABLE 2.

<u>Contaminant</u>	<u>Maximum Expected ppm</u>	<u>Maximum Tested with no adverse effect ppm</u>	<u>I<sub>2</sub> Demand** ppm I<sub>2</sub>/ppm Contaminant or composition</u>	<u>I<sub>2</sub> Stripping** ppm I<sub>2</sub>/ ppm Cont.</u>
NH <sub>4</sub> OH	20			2/.5
NH <sub>4</sub> <sup>+</sup> in (NH <sub>4</sub> ) SO <sub>4</sub>	20	1,000		2.2/10,000
NaOH	-			30/0.04
Ethanol	10	50,000		
Acetaldehyde	2	10,000		
NaCl	40	50,000		
Urea	35	10,000		
Lactic acid	13	10,000		
CalSoft	110	250	2/500	
ML11	110	40	1.5/100	
MDAC Pretreatment*			Oxidizing Agent	
Life Systems Pretreatment*			Contains I <sub>2</sub>	
Phenol	2		0.5/0.1, 1/0.5, 1.5/1	
Creatinine	8	8		
Ammonium hippurate	8	8		
<u>Humidity Condensate</u>				
NH <sub>3</sub>	18	18		
Ethanol	8	16		
Acetaldehyde	1	1		
<u>Simulated Urine Distillate without Carryover</u>				
NH <sub>3</sub>	20	40		
Ethanol	10	40		
Acetaldehyde	2	4		

\* See challenge section for composition page 10.

\*\* I<sub>2</sub> demand is a reduced I<sub>2</sub> residual compared to a control bed with DI water,  
I<sub>2</sub> stripping is an increased I<sub>2</sub> residual.

Table 2. cont

<u>Contaminant</u>	<u>Maximum Expected ppm</u>	<u>Maximum Tested with no adverse effect ppm</u>	<u>I<sub>2</sub> Demand ppm I<sub>2</sub>/ppm Contaminant or composition</u>	<u>I<sub>2</sub> Stripping ppm I<sub>2</sub>/ ppm Cont.</u>
--------------------	-------------------------------------	--	--	---

Simulated Urine Distillate with Carryover

Urea	75			
NaCl	45			
K <sub>2</sub> SO <sub>4</sub>	15			
KCl	9			
Creatinine	8			
NH <sub>4</sub> hippurate	8			
MgSO <sub>4</sub>	4			
Potassium phosphate (K <sub>3</sub> PO <sub>4</sub> )	1			
Phenol	2			

>2/composition

Simulated Wash Water after R0

ML11	40	40		
NaCl	20	20		
Lactic acid	10	10		
Urea	7	7		
<u>Raw Urine</u>	5000	200	1/1000	
Urine treated with MDAC		1000	>2/5000	
Urine treated with LS		1000	>2/5000	

Simulated Wash Water with Filtration

ML11	110			
NaCl	40			
Urea	35			
Lactic acid	13			

approx. 1.0/composition

Table 2. cont.

<u>Contaminant</u>	<u>Maximum Expected ppm</u>	<u>Maximum Tested with no adverse effect ppm</u>	<u>I<sub>2</sub> Demand ppm I<sub>2</sub>/ppm Contaminant or composition</u>	<u>I<sub>2</sub> Stripping ppm I<sub>2</sub>/ ppm Cont.</u>
<u>Simulated Wash Water after Flocculation and Filtration</u>				
ML11	50		0.5/composition	
NaCl	40			
Lactic acid	35			
Urea	13			
FeCl <sub>3</sub>	20			
<u>Filtered Shower Water</u>			>2/composition	
ML11	212			
<u>Flocculated &amp; Filtered Shower Water</u>			>2/composition	
FeCl <sub>3</sub>				

the process, however the subsequent charcoal and ion exchange columns would necessitate another unit for the final product.

In summary, the MCV has been shown to be able to process reclaimed water streams without degradation of the resin as long as the streams are within acceptable specifications. In the case of malfunctioning systems, excessive stripping of iodine from the bed would be the most damaging effect, which can be replaced as will be discussed later.

TABLE 3.

Tentative Wash Water Standards

Total Organic Carbon (TOC), mg/l	200
Specific Conductivity, $\mu\text{mho-cm}^{-1}$	2000
pH	5 to 7.5
Ammonia, mg/l	5
Turbidity, ppm $\text{SiO}_2$	10
Color, Pt-Co Units	15
Foaming	Nonpersistent more than 15 seconds
Odor	Nonobjectionable
Total Dissolved Solids (TDS), mg/l	1500
Urea, mg/l	50
Lactic acid, mg/l	50
NaCl, mg/l	1000
Microorganisms, number per ml	10

**Task 2.    RETROFIT FLIGHT PROTOTYPE MCV UNITS**

GFE prototype units serial numbers P2, P3, and P7 were modified to make them identical in function and operation to the Flight MCV and delivered to JSC. (See DD250 in Appendix)

**Task 3.    MANUFACTURE FLIGHT CERTIFIED RESIN**

Sufficient resin for 30 low residual MCV recharges and 16 high residual MCV recharges was manufactured, certified, and delivered to JSC. (See DD250 in Appendix)

#### TASK 4. RESIN REGENERATION

The MCV Resin has been shown to hold iodine in the  $I_3^-$  form. The high residual resins, i.e. those that produce measurable iodine residuals have been found to release iodine primarily as  $I_2$ , with a very small amount of  $I^-$  (approximately 0.2 ppm) accompanying the  $I_2$ . It should be possible, therefore, to regenerate a depleted high residual resin by simply replacing the  $I_2$ . If this can be accomplished without disassembling the MCV, a considerable savings in materials, but more importantly time is possible. In light of the previously discussed favorable results with reclaimed water, a MCV which could be regenerated in flight may provide a very attractive biocide dispensing system for long term missions involving closed systems.

Several tests were conducted with an 8 x 76 mm bed at a flow of 10 cc/min. Rather than try to exhaust a high residual bed and then regenerate it, a bed of low residual resin, 0.2 ppm, was used. A bed containing iodine crystals of approximately the same size as the resin bed was placed upstream and deionized water was pumped through. At room temperature, the saturation solubility of  $I_2$  in water is about 200 ppm. Experience has shown, however that a bed of fresh  $I_2$  crystals (under steady flow conditions) will initially produce water containing about 100 ppm, which will taper off after several hours to a steady value in the neighborhood of 50 ppm.

The first regeneration (actually  $I_2$  loading) attempt was conducted with a fresh low residual bed. The  $I_2$  crystal bed which was initially producing 115 ppm was removed when the effluent from the resin bed exceeded 2 ppm. After 100 hours the residual from the resin bed was still 5 ppm and showed no signs of tapering off; the test was terminated.

Figure 2 shows another test with a fresh low residual bed. This time the  $I_2$  bed was removed when the effluent residual reached 0.7 ppm, however no significant long term effect on the bed  $I_2$  residual was observed. The  $I_2$  bed was replaced in the feed stream until the effluent reached 1.5 ppm, when it was removed. The  $I_2$  residual continued to increase to about 4 ppm where it stabilized and then showed a rather erratic washout.

The most promising results are shown in Figure 3. A fresh bed was again installed, and an  $I_2$  bed placed in the line which had been washed so it was only producing 40 ppm  $I_2$ . It remained in the line until the resin bed was producing 1.8 ppm and then removed. The effluent from the resin bed immediately dropped below 1 ppm and gradually washed out to 0.2 ppm. The  $I_2$  bed which was conditioned until it was producing 63 ppm was reinstalled, and the  $I_2$  from the resin bed rapidly approached 3 ppm at which time the  $I_2$  bed was removed and the resin effluent immediately dropped to 2 ppm. The bed was then allowed to wash down to 1 ppm, and a bed of fresh  $I_2$  crystals installed. It was producing 98 ppm and the resin effluent went to 4 ppm in 1 hour; thus the  $I_2$  bed was removed. The resin effluent immediately dropped to 1.2 ppm and was allowed to return to 1 ppm when a bed of  $I_2$  which was producing 55 ppm was reinstalled. The resin effluent went immediately to 3 ppm but quickly returned to 2 ppm when it remained for 4 hours. The  $I_2$  bed was removed, and the next morning the effluent had washed to 1.6 ppm. A detail of the four hours the  $I_2$  bed was in line is shown in the inset on Figure 3.

The two four hour regeneration cycles shown on Figure 3. were in effect conducted with beds of high residual resin that had been exhausted. They clearly demonstrate that resin can be regenerated without removal from the cartridge and suggest that a system for inflight regeneration is feasible.

The sharp spike which occurs when the  $I_2$  bed is put on line would not be a problem in a flight system, since the resin bed would undoubtedly be feeding a storage tank where the spike would be lost by dilution.

It appears that a simple and reliable system could be developed for long term missions. Enough crystalline iodine for a mission could be stored in a single cartridge which could be inserted in the main or various water lines in the potable or wash water systems upon a signal from an  $I_2$  monitor. Additional work is necessary to investigate the behavior of  $I_2$  beds as well as the extensive cycling of a resin bed over a long period of time.



FIGURE 2, RESIN REGENERATION

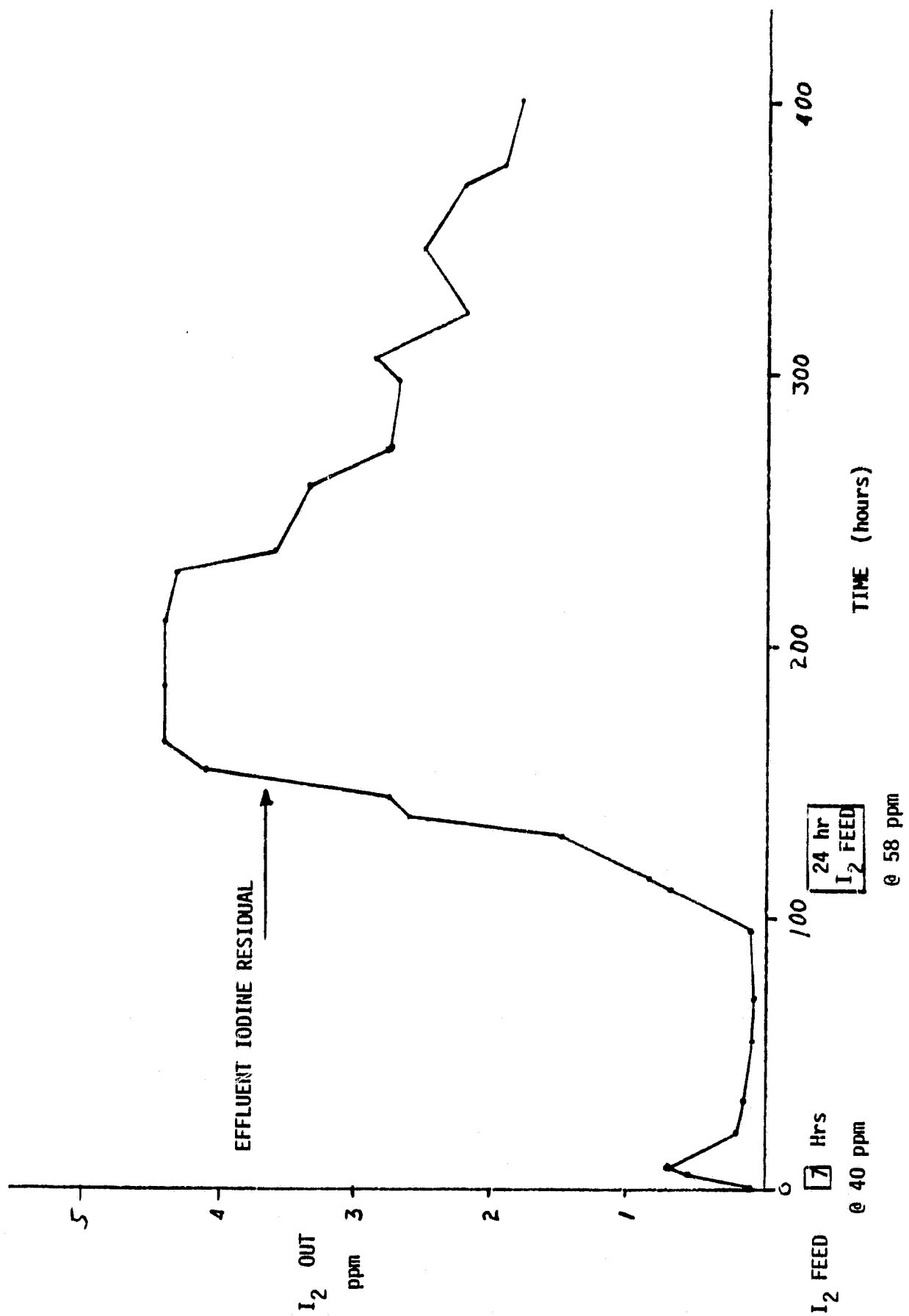
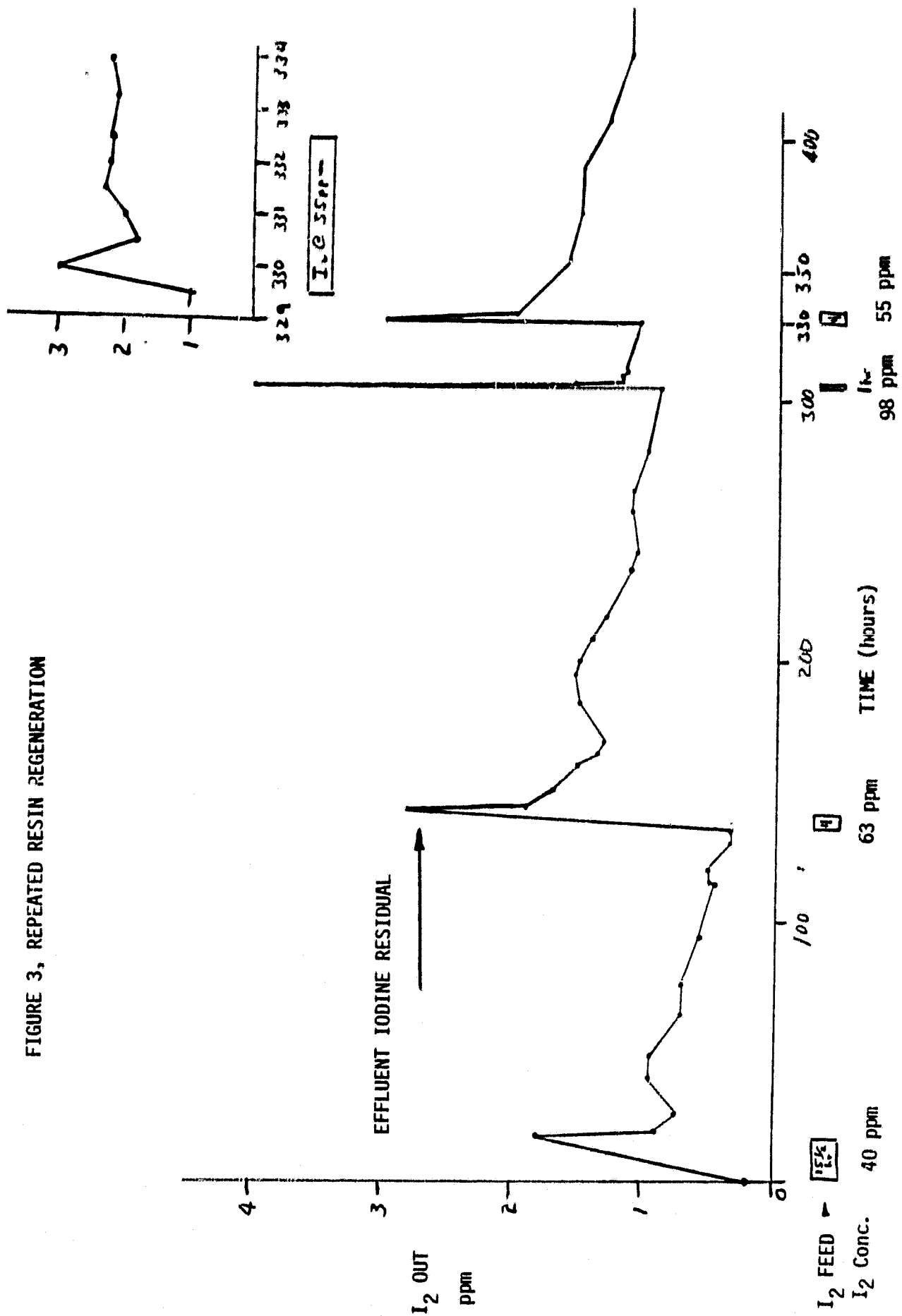


FIGURE 3, REPEATED RESIN REGENERATION



**Task 5. ADVANCED MCV PROTOTYPE**

An advanced MCV has been designed using lighter materials and fabrication procedures. The design is shown in Figure 4. The major weight savings is realized by the body being manufactured by spinning 300 series stainless steel sheet. The end cap is also 300 series sheet stock. The snap ring collar is replaced with a sheet metal clamp which is similar to a commercially available design. It is estimated that this design will save approximately 90 grams per unit or 0.2 lbs (present design 500 gm).

A prototype unit was fabricated according to this design concept and delivered (See DD250 in Appendix). The delivered unit is shown in Figure 5. This unit was designed around an off-the-shelf clamp, consequently all dimensions are not within the constraints of the 2x5 envelope. The prototype was subjected to all of the flight acceptance tests required for the previously certified units and passed satisfactorily. Consequently, flight certification of the new design by similarity with limited testing should be possible.

A resin cartridge which will simplify recharging both old and new units was designed and built, see Figure 6. The prototype was machined out of a block of polypropylene, thus the wall thickness is somewhat heavier (and rougher) than would be possible with an injection molded part. This cartridge will make recharging the MCV on site a very simple procedure. The cartridges are designed so they can also be reloaded and stored for reuse.

### COST ESTIMATES

Due to the similarity between the Advanced MCV design and the Flight Qualified MCV, it is estimated that it would cost in the neighborhood of \$10,000 to flight certify the Advanced MCV.

Fabrication costs for the Advanced MCV's should be approximately \$2,000 per unit in lots of 14 units. The resin cartridge feature of the Advanced MCV will mean that fewer units will be required. Recharge time will be reduced to a few minutes between flights, and a unit may be recharged with a new cartridge and re-installed rather than replaced with a recharged unit.

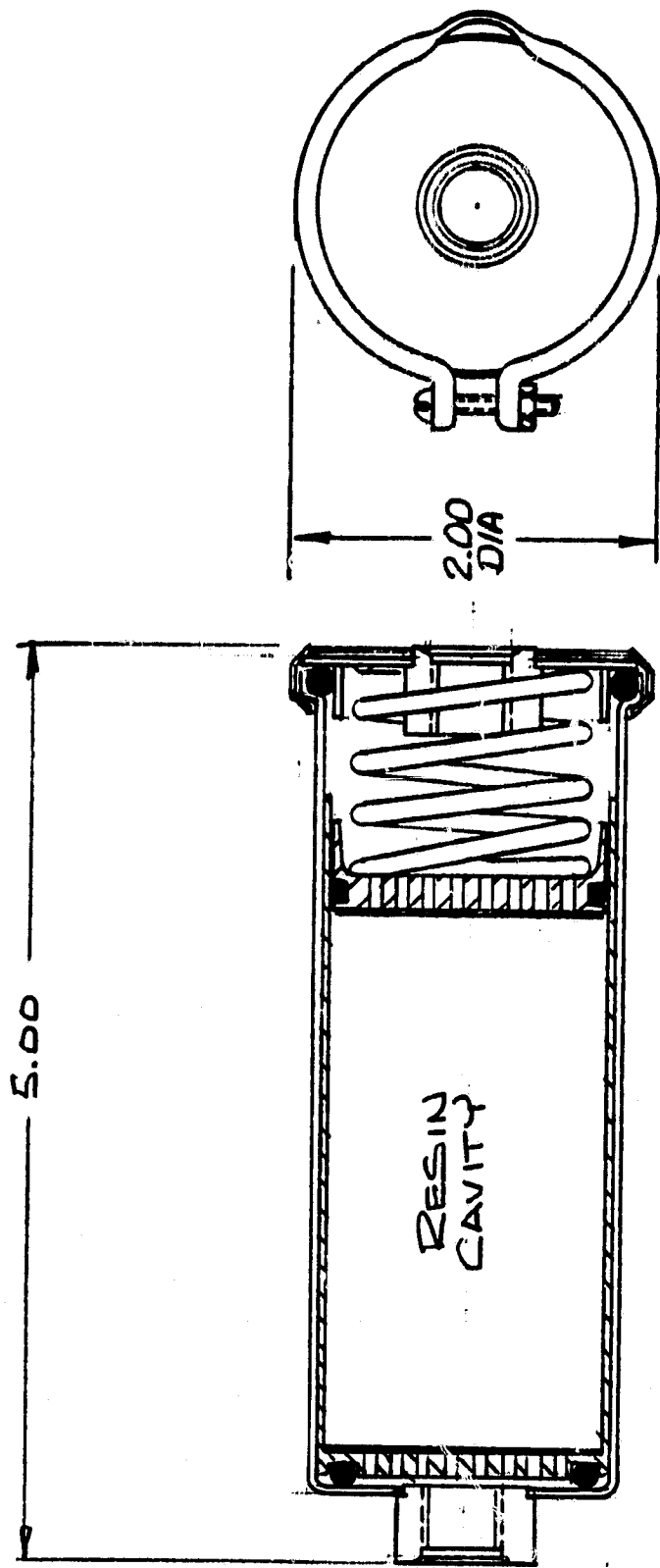
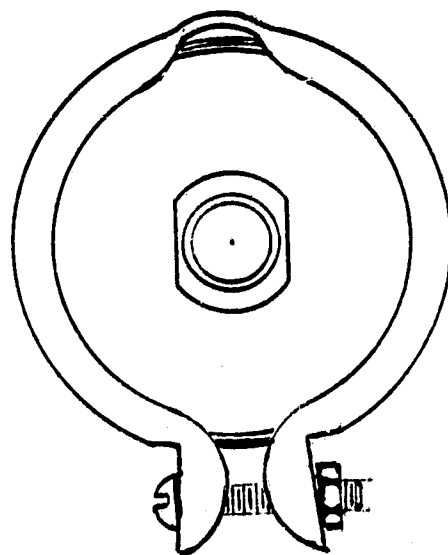
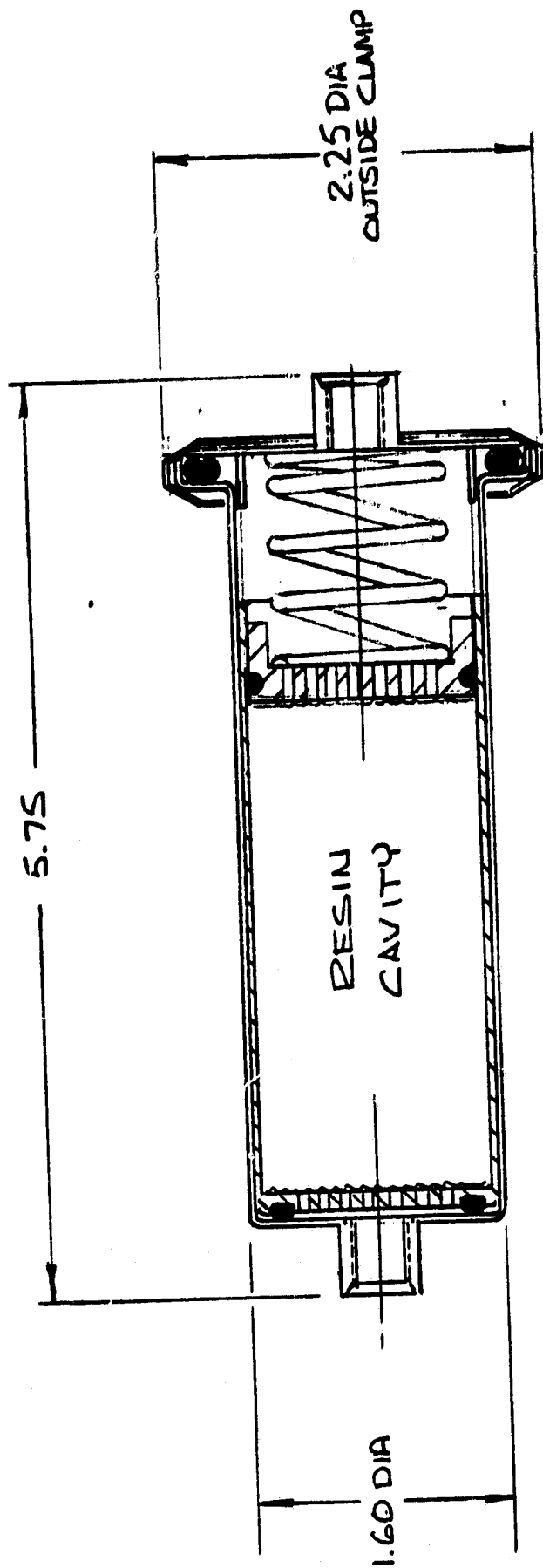


FIGURE 4, ADVANCED MCV



END VIEW

FIGURE 5  
ADVANCED  
MCV PROTOTYPE

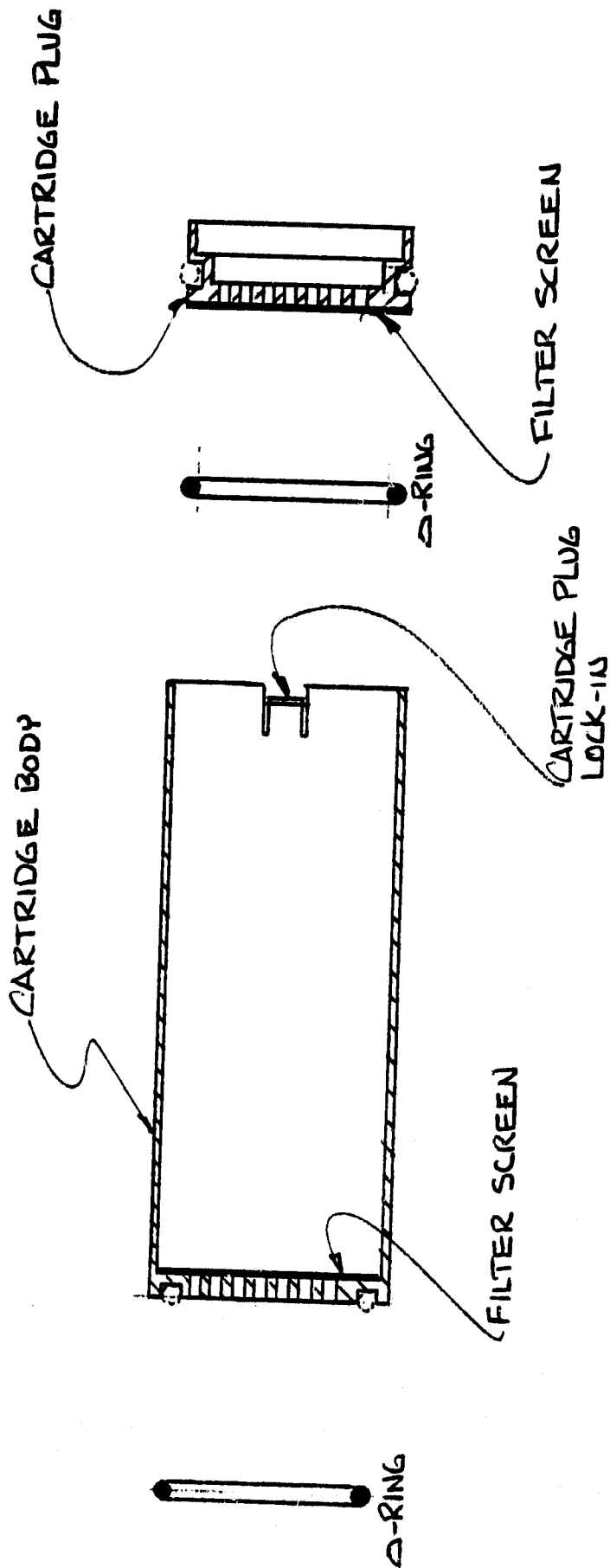


FIGURE 6  
MCV CARTRIDGE  
PROTOTYPE

## APPENDIX



<b>MATERIAL INSPECTION AND RECEIVING REPORT</b>		1. PROC. INSTRUMENT IDEN (CONTRACT)		2. ORDERING NO.	3. INVOICE NO.	7. PAGE 1 OF 1
		Contract Number NAS9-15854			DATE	8. ACCEPTANCE POINT
4. SHIPMENT NO.	5. DATE SHIPPED <b>10-24-79</b>	6. B/L TCN	9. DISCOUNT TERMS			
11. PRIME CONTRACTOR CODE UMPQUA RESEARCH COMPANY P.O. Box 791 Myrtle Creek, OR 97457		10. ADMINISTERED BY CODE				
1. SHIPPED FROM (If other than 9) CODE		FOR:	12. PAYMENT WILL BE MADE BY CODE			
3. SHIPPED TO CODE Transportation Officer, Bldg. 420 NASA-Lyndon B. Johnson Space Center Houston, TX 77058		14. MARKED FOR CODE Accountable Property Officer 807402 For reissue to: Richard Sauer, SE3 Bldg. 36, Rm 136				
16. ITEM NO.	18. STOCK/PART NO. (Indicate number of shipping containers - type of container - container number.)	17. QUANTITY SHIP/REC'D*	18. UNIT	19. UNIT PRICE	20. AMOUNT	
ru 3	Microbial Check Valve Prototype Part No. MCVP-02 Serial No's P2, P3, P7 Retrofitted to Flight Configuration	3		2000.	6000.	
ORIGINAL PAGE IS OF POOR QUALITY.						
21. PROCUREMENT QUALITY ASSURANCE			22. RECEIVER'S USE			
A. ORIGIN <input type="checkbox"/> PQA <input type="checkbox"/> ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.			B. DESTINATION <input type="checkbox"/> PQA <input type="checkbox"/> ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.			
DATE _____ SIGNATURE OF AUTH GOVT REP _____  TYPED NAME AND OFFICE _____			DATE _____ SIGNATURE OF AUTH GOVT REP _____  TYPED NAME AND OFFICE _____			
23. CONTRACTOR USE ONLY			*If quantity received by the Government is the same as quantity shipped, indicate by (✓) mark. If different, enter actual quantity received below quantity shipped and encircle.			

<b>MATERIAL INSPECTION AND RECEIVING REPORT</b>		1. PROC. INSTRUMENT IDEN (CONTRACT)		ORDER NO.	6. INVOICE NO.	7. PAGE 1	OF 1
		Contract Number NAS9-15854			DATE	8. ACCEPTANCE POINT	
2. SHIPMENT NO.  URC00630-1	3. DATE SHIPPED  30 June 80	4. B/L  TCN		5. DISCOUNT TERMS			
9. PRIME CONTRACTOR CODE  UMPQUA RESEARCH COMPANY P. O. Box 791 Myrtle Creek, OR 97457		10. ADMINISTERED BY CODE					
11. SHIPPED FROM (If other than 9) CODE		FOB:		12. PAYMENT WILL BE MADE BY		CODE	
13. SHIPPED TO CODE  Transportation Officer, Bldg. 420 NASA-Lyndon B. Johnson Space Center Houston, TX 77058		14. MARKED FOR CODE  Accountable Property Officer 807402 For reissue to: Richard Sauer, SE3 Bldg. 36, Room 136					
15. ITEM NO.	16. STOCK/PART NO. (Indicate number of shipping containers-type of container-container number.)	DESCRIPTION		17. QUANTITY SHIP'D/REC'D*	18. UNIT	19. UNIT PRICE	20. AMOUNT
1		Bulk high residual resin		1		2000.00	2000.00
1		Bulk low residual resin		1		2000.00	2000.00
THESE ARE FLIGHT ITEMS							
21. PROCUREMENT QUALITY ASSURANCE					22. RECEIVER'S USE		
<input type="checkbox"/> PGA <input type="checkbox"/> A. ORIGIN ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.		<input type="checkbox"/> PGA <input type="checkbox"/> B. DESTINATION ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.			Quantities shown in column 17 were received in apparent good condition except as noted.		
DATE		SIGNATURE OF AUTH GOVT REP		DATE RECEIVED		SIGNATURE OF AUTH GOVT REP	
TYPED NAME AND OFFICE		TYPED NAME AND TITLE		TYPED NAME AND OFFICE		*If quantity received by the Government is the same as quantity shipped, indicate by (✓) mark, if different, enter actual quantity received below quantity shipped and encircle.	
23. CONTRACTOR USE ONLY							

<b>MATERIAL INSPECTION AND RECEIVING REPORT</b>		1. PROC. INSTRUMENT IDEN (CONTRACT)		ORDER NO.		6 INVOICE NO.		7 PAGE 1 OF 1	
		Contract Number NAS9-15854				DATE		8 ACCEPTANCE POINT	
2. SHIPMENT NO. C00630 -2Z		3. DATE SHIPPED 30June80		4. B/L TCN		5. DISCOUNT TERMS			
9. PRIME CONTRACTOR CODE  UMPQUA RESEARCH COMPANY P. O. Box 791 Myrtle Creek, OR 97457				10. ADMINISTERED BY CODE					
11. SHIPPED FROM (If other than 9) CODE				FOB:		12. PAYMENT WILL BE MADE BY CODE			
13. SHIPPED TO CODE  Transportation Officer, Bldg. 420 NASA-Lyndon B. Johnson Space Center Houston, TX 77058				14. MARKED FOR CODE  Accountable Property Officer 807402 For reissue to: Richard Sauer, SE3 Bldg. 36, Rm 136					
15. ITEM NO.	16. STOCK/PART NO. (Indicate number of shipping containers-type of container-container number.)	DESCRIPTION		17. QUANTITY SHIP'D/REC'D	18. UNIT	19. UNIT PRICE	20. AMOUNT		
1		Advanced lightweight MCV prototype PB		1		1000.00	1000.00		
THIS ITEM IS NOT FOR FLIGHT									
21. PROCUREMENT QUALITY ASSURANCE						22. RECEIVER'S USE			
<input type="checkbox"/> PQA <input type="checkbox"/> A. ORIGIN ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.			<input type="checkbox"/> PQA <input type="checkbox"/> B. DESTINATION ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.			Quantities shown in column 17 were received in apparent good condition except as noted.			
DATE			SIGNATURE OF AUTH GOVT REP			DATE RECEIVED		SIGNATURE OF AUTH GOVT REP	
TYPED NAME AND OFFICE			TYPED NAME AND TITLE			TYPED NAME AND OFFICE			
23. CONTRACTOR USE ONLY						*If quantity received by the Government is the same as quantity shipped, indicate by (✓) mark, if different, enter actual quantity received below quantity shipped and encircle.			